Scientific Inquiry

PS-1 The student will demonstrate an understanding of how scientific inquiry and technological design, including mathematical analysis, can be used appropriately to pose questions, seek answers, and develop solutions.

PS-1.4 Design a scientific investigation with appropriate methods of control to test a hypothesis (including independent and dependent variables), and evaluate the designs of sample investigations.

Taxonomy Level: 6.2-C Create Procedural Knowledge
5.2-B Evaluate Conceptual and Procedural Knowledge

Key Concepts:
Scientific investigation: Hypothesis, Independent variable, Dependent variable
Methods of control: Controlled variable, Control group

Previous/Future knowledge: In the 4th grade (4-1.3), students summarized the characteristics of a simple scientific investigation that tests one manipulated variable at a time. In the 5th grade (5-1.3), students planned and conducted controlled scientific investigations, manipulating one variable at a time. In the 6th and 7th grades (6-1.1 and 7-1.1), students conducted controlled scientific investigations, and in the 8th grade (8-1.1), students designed controlled scientific investigations. In the 7th grade (7-1.5), students explained the relationships between independent and dependent variables in controlled scientific investigations. While students identified questions suitable for generating a hypothesis (5-1.1) that could be answered through scientific investigation (7-1.2) and (8-1.4), in Physical Science students will design and evaluate designs of controlled scientific investigations to test a hypothesis with stated independent and dependent variables. In chemistry (C-1.4) and in physics (P-1.4) students will expand the idea of designing and evaluating scientific investigations.

It is essential for students to

- Design a controlled scientific investigation in which one variable at a time is deliberately changed and the effect on another variable is observed while holding all other variables constant.
  The steps in designing an investigation include:
  - Stating the purpose in the form of a testable question or problem statement
  - Researching information related to the investigation
  - Stating the hypothesis
  - Describing the experimental process
    - Planning for independent and dependent variables with repeated trials
    - Planning for factors that should be held constant (controlled variables)
    - Setting up the sequence of steps to be followed
    - Listing materials
    - Planning for recording, organizing and analyzing data
  - Planning for a conclusion statement that will support or not support the hypothesis
- Understand that scientific investigations are designed to answer a question about the relationship between two variables in a predicted "cause-effect relationship."
- Understand that the statement that predicts the relationship between an independent and dependent variable is called a *hypothesis*.
- Understand that the *independent variable* is the variable that the experimenter deliberately changes or manipulates in an investigation.
- Understand that the *dependent variable* is the variable that changes in an investigation in response to changes in the independent variable.

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- Understand that the independent variable is the "cause" and the dependent variable is the "effect" in the "cause-effect" relationship that is predicted.
- Understand that all the other possible variables in the investigation should be held constant so that only one variable (the independent) is tested at a time. The variables which are held constant are called *controlled variables*.
- Understand that the investigator should conduct repeated trials to limit random error in measurements.
- Understand that, when appropriate, a *control group* is set up as a basis of comparison to test whether the effects on the dependent variable came from the independent variable or from some other source.

It is also essential for students to

- Evaluate the design of an experiment by assessing whether the steps of the investigation are presented.
- Evaluate the methods by which the investigation was conducted to determine:
  - Whether independent and dependent variables are appropriate for testing the hypothesis;
  - Whether only one variable is changed at a time by the investigator;
  - Which variables are, or should have been, controlled;
  - Whether data was collected with adequate repeated trials, organized and analyzed properly;
  - Whether the conclusion is logical based on the analysis of collected data.

Teacher Note: Many science laboratory activities simply give students procedures to follow, data to collect and graph, and questions to answer that verify their learning of the concepts. Science learning can be more interesting to students if they are given the opportunity to explore and wonder "why" more often. If students conduct an investigation in which something unexpected or unusual happens and then are asked to predict why it happened, they feel more involved in the learning. Then, if they are asked to *design an experiment* to see if their prediction is correct, they will feel empowered by the activity. These activities are often called "Open Inquiry" or "Guided Inquiry" depending on how much instruction is provided. Teachers should encourage students to be curious and wonder why things happen. Science fair projects can be a perfect opportunity for students to conduct these kinds of activities. Instruction and guidance should be provided to insure that proper investigative procedures are followed.

It is not essential for students to

- Understand the null hypothesis process.
- Perform statistical analysis on the data to evaluate the experimental design.

Assessment Guidelines:

The first objective of the indicator is to *design* a scientific investigation with appropriate methods of control to test a hypothesis; therefore the primary focus of assessment should be for students to demonstrate understanding of the components of a properly designed scientific investigation.

In addition to *design*, students should be able to:

- *Classify* the types of variables and constants in a controlled investigation;
- *Summarize* the components of a controlled scientific investigation.

Another objective of this indicator is to *evaluate* the designs of sample investigations; therefore, the primary focus of assessment should be to critique the components of a controlled scientific investigation by determining whether the investigation has met the criteria for testing a particular hypothesis.−

In addition to *evaluate*, students should be able to:

- *Interpret* the data to *infer* a relationship between the variables predicted by the hypothesis;
- *Interpret* the data to determine if the conclusion is valid;
- *Check* the investigation results to determine if the hypothesis is supported;
- *Relate* the hypothesis to an appropriate scientific investigation;
- *Identify* the components of a scientific investigation.